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Effects of genetic merit for fertility traits on phenotypic performance of lactating Holstein cows

Key external stakeholders:

Dairy farmers, Irish Cattle Breeding Federation, AI companies, reproductive biologists.

Practical implications for stakeholders:

This study developed and validated a novel genetic model of fertility in lactating dairy cows.

- The results clearly highlighted the benefits of selecting for improved genetic merit for fertility on the phenotypic reproductive performance of lactating Holstein cows. Of note, excellent fertility performance was achieved without a detrimental effect on phenotypic milk production.
- Cows with poor genetic merit for fertility traits displayed multiple physiological defects that collectively explain the main areas of reproductive loss.

Main results:

A lactating Holstein cow genetic model of fertility was generated by selecting animals with similar proportions of Holstein genetics and similar genetic merit for milk production traits, but with extremes of good (Fert+) or poor (Fert-) genetic merit for fertility traits. The main results were:

- Phenotypic milk production was similar in both genotypes, but fertility performance was markedly superior in the Fert+ cows compared with the Fert- cows. This was verified by also examining the milk production and fertility performance of a large number of Fert+ and Fert- animals in the national database.
- The Fert+ cows maintained greater body condition score (BCS) throughout lactation, in agreement with the observation that they also maintained greater circulating concentrations of the key metabolic hormones insulin and IGF-I.
- The incidence of both 'silent heats' and ovulation failure after displaying heat was greater in Fert- cows. This likely represents a substantial area of reproductive loss.
- Fert+ cows had a larger dominant follicle at ovulation, and during the luteal phase had a larger corpus luteum and greater concentrations of progesterone.

Opportunity / Benefit:

The immediate benefit of this research is the clear indication that selecting for improved genetic merit for fertility traits will result in improved phenotypic fertility performance. This has positive implications for Irish dairy farmers, the current national breeding programme, and Irish AI companies. In the longer term, this unique animal model will allow us to improve our understanding of the basic physiological mechanisms responsible for fertility failure in lactating Holstein cows.

Collaborating Institutions:

Teagasc, UCD.

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1. Project background:

Despite the crucial role fertility plays in maximizing economic output, reproductive efficiency in dairy cows has decreased during the past half century both in Ireland and internationally. In Ireland, some of this decrease has been attributed to the intense selection for milk production traits and the associated introduction of North American Holstein genes.

To address the problem of decreasing fertility, the Irish national breeding program moved from being predominantly focused on milk production traits to a more holistic multi-trait index called the Economic Breeding Index (EBI). Introduced in 2001, the EBI included production and nonproduction traits, thus identifying animals of superior genetic merit for delivering on-farm profit. Since its introduction, the EBI has evolved to include 6 sub-indexes. Of these, milk production (38.1%) and fertility and survival (34.8%) have the greatest weighting (weighting indicated in parentheses).The fertility sub-index itself is composed of two traits: calving interval (23.2%) and survival (11.5%). Good genetic merit for fertility traits requires negative estimated breeding values (EBV) for calving interval and positive EBV for survival.

In previous studies comparing models of good and poor fertility, observed differences in phenotypic fertility performance were generally confounded with genetic merit for milk yield and phenotypic milk production. Therefore, the aim of this study was to characterize the phenotypic performance of cows with similar genetic merit for milk production traits and similar proportions of Holstein genes, but with either good (Fert+) or poor (Fert-) genetic merit for fertility traits.

2. Questions addressed by the project:

- Would differences exist between Fert+ and Fert- cows in fertility performance, milk production, body reserve mobilization and circulating concentrations of metabolic hormones and metabolites?
- Does genetic merit for fertility traits impact follicular and corpus luteum development, reproductive hormone profiles and oestrous behaviour during the oestrous cycle?
- Are there detectable differences in oocyte and embryo morphology and the abundance of key genes associated with oocyte and embryo developmental competence?
- Are there temporal differences in the pattern of somatotropic axis gene expression in liver tissue?

3. The experimental studies:

Using the official dairy evaluations published by the Irish Cattle Breeding Federation (ICBF, Bandon, Co. Cork, Ireland), the national dairy cattle database was screened for heifers due to calve for the first time in Spring 2008 and again in spring 2009. Restrictions were placed on the EBV for milk production (between +200 and +900 kg) and proportion of Holstein genetics (>75%). Within this population, heifers with extreme positive (i.e., poor fertility) and negative (i.e., good fertility) EBV for calving interval were identified. Poor-fertility (**Fert−**) heifers were restricted to animals where both the sire and maternal grand-sire had positive EBV for calving interval. Conversely, good-fertility (**Fert+**) heifers were restricted to animals where both the sire and maternal grand sire had negative EBV for calving interval. Heifers identified as being available for purchase were screened for infectious diseases. A total of 26 nulliparous Fert− and 26 nulliparous Fert+ cows were purchased and moved to the Animal & Grassland Research and Innovation Centre, Moorepark. Within the Irish national herd, these animals were representative of the top quartile in genetic merit for milk production, whereas the Fert+ and Fert− groups represented the top 20% and bottom 5% for calving interval, respectively.

The animals were run as a single herd, with identical general husbandry and nutritional management. Milk production, BCS, and bodyweight measurements were recorded routinely, and blood samples were collected at frequent intervals to assess hormonal and metabolite indicators of bioenergetic status. In 2008 (all first lactation animals), the heifers were bred as normal, and reproductive performance was recorded. In 2009 (mix of first and second lactation), breeding was delayed to allow detailed measurements to be collected during early and mid lactation. These measurements included:

- Collection of immature cumulus-oocyte complexes using transvaginal ovum pick-up for assessment of morphology and expression of key genes associated with competence;

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- Collection of embryos following superovulation treatment by non-surgical flushing of the uterine horns on day 7 after AI for assessment of morphology and expression of key genes associated with competence;
- Collection of daily blood samples and daily transrectal ultrasound measurements of ovarian follicular and corpus luteum dynamics for one full oestrous cycle;
- Collection of liver tissue by percutaneous punch biopsy at weeks -3, 1, 8, 20 and 34 relative to parturition to assess the expression of genes involved in the somatotropic axis.

4. Main results:

- The Fert+ cows had greater daily milk yield (19.5 vs. 18.7 kg/d), shorter interval from calving to conception (85.6 vs. 113.8 d), and fewer services per cow (1.78 vs. 2.83). No difference between groups in grass dry matter intake, energy balance, or body weight was observed. The Fert+ cows maintained greater BCS during mid (2.84 vs. 2.74 units) and late lactation (2.82 vs. 2.73 units). Circulating concentrations of insulin-like growth factor-I were greater throughout the gestation-lactation cycle in Fert+ cows (148.3 vs. 128.2 ng/mL). The Fert+ cows also had greater circulating concentrations of insulin during the first 4 wk of lactation (1.71 vs. 1.24 µIU/mL). Analysis of records from national herd data verified the association between genetic merit for fertility traits and phenotypic reproductive performance; Fert+ cows (n = 2,436) required 11.1 d less to re-calve than did Fert− cows (n = 1,388), and the percentage of cows that successfully calved for the second time within 365 and 400 d of the first calving was 8 and 13% greater for Fert+ compared with Fert− cows, respectively.
- There was no substantial difference between Fert+ and Fert- cows in either oocyte or embryo morphology, or in the abundance of transcripts associated with oocyte or embryo developmental competence.
- The Fert+ cows tended to have fewer follicular waves (2.2 vs. 2.7) and had a shorter oestrous cycle (21.0 vs. 25.1 d) than Fert− cows. During the first 13 d of the cycle, Fert+ cows developed a corpus luteum that was 16% larger than that in Fert− cows. Circulating progesterone concentrations were 34% greater in Fert+ than in Fert− cows (5.15 vs. 3.84 ng/mL, respectively) from d 5 to 13. During the final follicular wave, maximum preovulatory follicle diameter was larger in Fert+ than Fert− cows (17.9 vs. 16.8 mm, respectively), but circulating concentrations of oestradiol were not different between genotypes. A greater proportion of Fert− cows ovulated to a ‘silent heat’ than Fert+ cows (22 vs. 2%, respectively). Of cows that showed behavioural oestrus, a greater proportion (P = 0.04) of Fert− cows failed to ovulate a DF (0 vs. 14% for Fert+ and Fert−, respectively). Amongst the cows that showed behavioural oestrus, Fert+ cows had 41% greater mean activity count; however, no difference was seen in mounting behaviour between genotypes.
- The Fert+ cows had increased mean expression of *IGF-I* mRNA during the study; however, the difference in *IGF-I* mRNA abundance between Fert+ and Fert− cows was most pronounced at week 20 and 35 of lactation. The abundance of *IGFBP3* and *ALS* transcripts was similar in Fert+ and Fert− cows for the duration of the study, but Fert− cows, had greater expression of low molecular mass binding proteins (*IGFBP2-6)*. This has important implications for the half-life of IGF-I in circulation. Genetic merit for fertility traits affects hepatic expression of key genes of the somatotropic axis regulating the synthesis, bioavailability, and stability of circulating IGF-I.

5. Opportunity/Benefit:

The results clearly highlight the importance of selecting for improved fertility traits in dairy cattle, which will provide long-term benefits to Irish dairy farmers. There is an opportunity for AI organisations to improve the marketing of Irish bulls with a strong fertility sub-index, both nationally and internationally.

6. Dissemination:

Main publications:

Cummins, S. B., Lonergan, P., Evans, A.C.O., Berry, D.P., Evans, R.D. and Butler, S.T. (2012) ‘Genetic merit for fertility traits in Holstein cows: I. Production characteristics and reproductive efficiency in a pasture-based system.’ *Journal of Dairy Science* 95:1310-1322.

Cummins, S. B., Lonergan, P., Evans, A.C. and Butler, S.T. (2012) ‘Genetic merit for fertility traits in Holstein cows: II. Ovarian follicular and corpus luteum dynamics, reproductive hormones, and estrus behavior.’ *Journal of Dairy Science* 95:3698-3710.

Cummins, S. B., Waters, S.M., Evans, A.C., Lonergan, P. and Butler, S.T. (2012) ‘Genetic merit for fertility traits in Holstein cows: III. Hepatic expression of somatotropic axis genes during pregnancy and lactation.’ *Journal of Dairy Science* 95:3711-3721.

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Conferences and Open Days:

Cummins, S.B. and Butler, S.T. (2009) 'The effect of genetic merit for fertility on cow performance.' Pages 57-59 in Moorepark '09 Open Day 'Irish Dairying: new thinking for challenging times', 18th June 2009, Moorepark, Fermoy, Co. Cork. www.agresearch.teagasc.ie/moorepark/Publications/pdfs/Open%20Day%20Moorepark%202009.pdf

Berry, D.P., Buckley, F., Butler, S.T., Cummins, S.B. and Cromie, A. (2012) 'Breeding for fertility in Irish dairy cows.' Pages 30-38 in conference proceedings 'Dairy cow fertility: reproductive performance for efficient pasture-based systems', 11th and 12th April 2012, Cork. www.agresearch.teagasc.ie/moorepark/publications/pdfs/DairyCowFertilityConference.pdf

Popular publications:

Cummins, S.B. and Butler, S.T. (2011) High and low fertility in dairy cows. TResearch 6(1): 26-27.

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